

# RISK-BASED ANALYSIS OF THE DANISH PORK *SALMONELLA* PROGRAM, PAST AND FUTURE

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**Introduction** The question of where in the production system to best implement control *Salmonella* policies often ends up between the farm or the abattoir, as control policies further downstream e.g. the kitchen are difficult to implement. The Danish on-farm program involves classification of herd *Salmonella* status based on statistically based serological sampling. Herds with high seroprevalence levels receive special attention and financial penalties that encourage the reduction of *Salmonella* levels. As the program moves into its second decade, it is beneficial to evaluate the impact it has had on human risk of salmonellosis due to Danish pork.

All public policy efforts directed to the farm or the abattoir assume there is a connection between *Salmonella* in pigs and pork and salmonellosis in humans. It is assumed that reduction in pathogen prevalence on-farm and in the abattoir will result in reduced illness attributable to that pathogen-food combination, even if that attribution is not directly measurable. Every carcass tested, every HACCP implemented assumes there is a connection between efforts made on the farm or in the abattoir and human health. The goal of this analysis was to use that assumed connection and to evaluate some long range (10 year) control options for the Danish pork production system.

**Materials and Methods** The method used was to generate a computer simulation model constructed of a series of Excel workbooks; one for each simulated year and scenario (Figure 1). Each workbook had four modules representing the key processes affecting *Salmonella* levels in pigs leaving the farm, on carcasses after slaughter, and pork attributed human cases of *Salmonella* (PAHC).

The initial value (INITVAL) module used data on the *Salmonella* seroprevalence distribution of swine herds participating in the Danish control program. For the retrospective analysis, described below, it used observed data for years 1995 to 2003. The data were derived from the 1) National *Salmonella* surveillance data containing seroprevalence on the herd-level; 2) and data from the traditional meat inspection providing information about herd size. The average annual seroprevalence was used to categorize herds into 11 seroprevalence categories.

The production (PROD) module calculated the number pigs from various seroprevalence categories; using data from the INITVAL module. The resulting flow of pigs from each category was fed into the slaughter (SLAUG) module. This module calculated the annual number of *Salmonella* positive carcasses as a function of pigs in each seroprevalence category. It is based on a regression equation, fitted from existing national data on pooled (n=5) of carcass swab cultures. The coefficient of the regression equation was then adjusted to correlate with the observed national carcass swab data given the on-farm seroprevalence distribution for that year (1994-2005). This adjustment process allows modeling of the undefined but real improvements in general abattoir processes that have reduced *Salmonella* levels on carcasses.

The attribution (ATTRIB) module used the output from SLAUG to simulate the PAHC as a function of carcass contamination. To create this function it used historical data on the attributions made between pork produced and pork associated human illness for years 1999-2003 as published in the yearly Danish Zoonoses reports ([www.DFVF.dk](http://www.DFVF.dk)).

As stated, the base model consisted of an Excel® workbook with one sheet for inputs and one

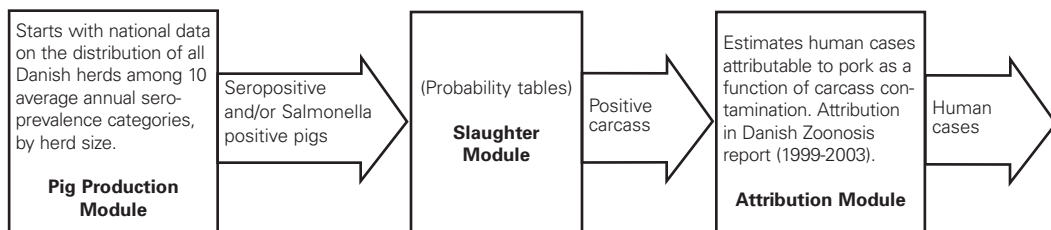


Figure 1: A Systems model of the production pork attributed Danish human salmonellosis cases from Danish produced pork.

for each of the above described modules. Stochastic simulations were implemented by use of @Risk (Palisade, CA USA). Thus providing 95% confidence intervals for all key outputs. The series of spreadsheets used to simulate all scenarios described below is available on <http://www.vrac.iastate.edu/~scorns/shurd/>.

There were two types of analysis conducted: *retrospective* and *prospective*. The objective of retrospective analysis (1994-2003) was to isolate the separate effects of reductions in on-farm seroprevalence levels from improvements in the abattoir processes. A separate spreadsheet was created for each year, to include each year's specific data on herd seroprevalence distribution, herds producing pigs, and observed prevalence of positive carcasses. For each year, the output of interest were PAHC and total number of positive carcasses. Five scenarios were simulated. The Historical scenario used yearly changing data on seroprevalence distribution and the abattoir coefficient to recreate the likely course of declining positive carcasses and PAHC from 1994 to 2003. This

was the baseline for comparison to other simulated scenarios. The other scenarios include changes in the on-farm seroprevalence only with no changes in abattoir process and no change in on-farm seroprevalence in the presence of continued abattoir improvements.

For the prospective analysis, six different forward looking scenarios were used to explore possible future outcomes as on-farm and abattoir procedures were varied over a 10 year planning horizon (2003-2013). The first two scenarios compared how continued changes in on-farm *Salmonella* levels alone impacted the resulting number of *Salmonella* positive carcasses and attributable human cases. The other four scenarios compared different combinations of improvements.

Additionally, the static (one year, immediate) effect on PAHC of carcass decontamination as applied to various portions of the slaughter pig population was analyzed. Currently, hot water decontamination is applied only to carcasses from Level 3 pigs. A model was created using 2004 data simulating decontamination of various percentages of the slaughter pig population. The decontamination parameter is set to be 90% effective at reducing *Salmonella* contamination.

**Results** In the retrospective analysis, the Historical scenario shows a reduction of PAHC from 351 to 202 (42%) comparing 1995 to 2003. This scenario reflects the effects of changes in the on-farm seroprevalence in combination with abattoir process improvements. Looking at the effect of on-farm interventions only (Abattoir95) shows there was an early significant decrease in number of positive carcasses due solely to the on-farm control program; reduction of approximately 73 (21%) mean number PAHC (1995 versus 1998). However, the effect of this on-farm program alone did not continued much beyond 1998; the annual number of PAHC staying around the 1998 level of 278. In the scenario of no on-farm control program beyond 1995 levels (Farm95), i.e. all improvements in the abattoir, there was downward trend similar to that simulated in the Historical scenario; reduction from 351 cases per year to 234.

The prospective analysis showed that continued reductions on-farm (ImpF) will result in minimal reductions in positive carcasses or human risk (159 PAHC/yr in 2004 to 144 in 2013). Also, there is little predicted change in risk if on-farm levels do not revert back (RevF) beyond the high levels of the early years (1995 to 1997). These data also show that continued improvement in abattoir methods, with no further changes on-farm (Farm2003ImpAb) will continue to reduce positive carcasses and expected human cases at a slow steady rate. With no more changes on-farm, the predicted number of PAHC in 2013 is around 110; significantly less than the 152 predicted in

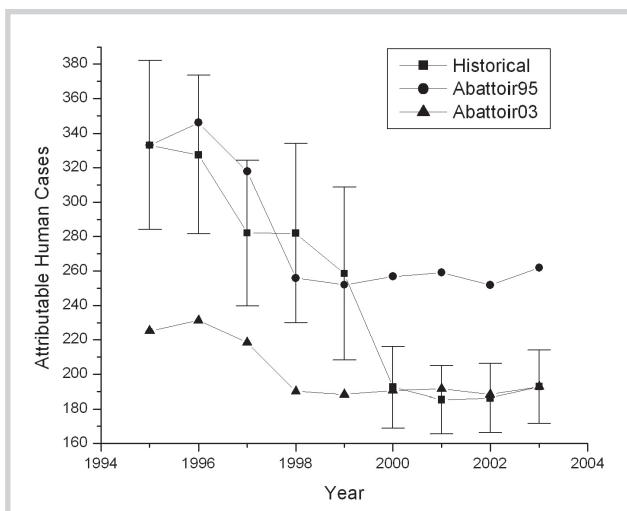


Figure 2: Comparison of simulated total annual number of pork attributable human cases if on-farm control methods were used with 1995 (Abattoir95) or 2003 (Abattoir03) slaughter quality parameters.

2003. For on-farm improvements only, The predicted number of PAHC in 2013 was not significantly less than the 2003 starting point.

The static (2004) decontamination scenarios showed, if 10% of the slaughter pig population was decontaminated there would be a reduction in the predicted number of PAHC/yr to 126 from 152, but the results are not significantly different. Decontamination of all carcasses would result in significant 10-fold reduction in the number of pork attributed *Salmonella* cases (152 to 15).

This study compared the relative impact of *Salmonella* control efforts implemented on-farm since 1994 with efforts occurring at the same time in the abattoir. Overall, this study demonstrates that, except for the first few years (1994-1998), the on-farm program had minimal impact in reducing the number of positive carcasses and pork attributable human cases (PAHC). Most of the reductions in the PAHC up to 2003 were, due to ill-defined improvements in slaughter hygiene. The various prospective scenarios out to 2013 show a similar conclusion that on-farm efforts at *Salmonella* reduction, similar to those in the past, will not markedly improve public health. This is largely due to the fact that herds in the low seroprevalence categories still sell *Salmonella* infected pigs.

A few recommendations for Denmark may be deduced from this analysis:

- Consider a limited or reduced investment in on-farm control; just enough to maintain the current infection status.
- Remain open to new on-farm technologies that may make *Salmonella* control more cost-effective.
- Explore and invest in new abattoir specific interventions.
- Consider carcass decontamination options for all carcasses.
- Continue to refine this model and other systems models that connect underlying current policy options.

## References

For a full report with references, see the International Epi Lab, [www.dvfv.dk](http://www.dvfv.dk)

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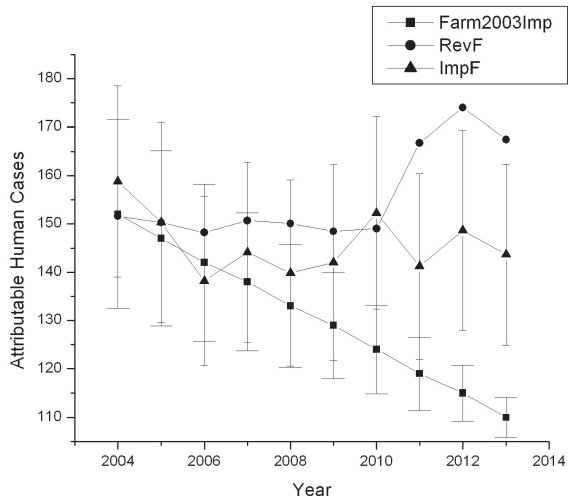


Figure 3: Comparison of simulated pork attributable human cases per year based on holding on-farm seroprevalence levels at 2003 levels and improving abattoir methods (Farm2003ImpAb); reverting on-farm methods to 1995 values while keeping abattoir values constant (RevF); and continuing to improve on-farm methods while keeping abattoir values constant (ImpF).